

1     **WHAT IS CLAIMED IS:**

2             1. A method for controlling parallel operation of UPS modules by  
3     providing respective UPS modules with identical control logic and functional  
4     capabilities for self-initiated role detection, master arbitration, and parallel  
5     processing, and the capability to elect a virtual master among all the UPS  
6     modules for coordinating inter-unit signaling and controlling parallel operation,  
7     such that when the virtual master is found failed, all other parallel UPS modules  
8     will initiate a master arbitration to elect a new virtual master for coordinating the  
9     parallel operation.

10            2. The method for controlling parallel operation of UPS modules as  
11     claimed in claim 1, wherein respective UPS modules have functional capabilities  
12     to operate in the following operation modes:

13            self-initiated role detection mode used for determining the functional  
14     role of respective UPS module after the arbitration process as either a new  
15     entrant, virtual master or virtual slave;

16            new entrant operation mode wherein the UPS module first checks for a  
17     virtual master in the parallel UPS system and if the virtual master exists, the  
18     respective UPS module will enter a wait for the virtual master to issue a call-slave  
19     command, and from which the respective UPS module will switch itself over to  
20     the slave operation mode; but if the virtual master does not exist, the respective  
21     UPS module will initiate the master arbitration for electing a virtual master;

22            master operation mode wherein the elected master sequentially checks  
23     the status of new entrants and virtual slave in the system, and then requests a  
24     response from the existing virtual slaves, and collects their operation data for

1 controlling the parallel operation; and  
2 slave operation mode wherein the UPS module checks for a virtual  
3 master in the UPS system; if it does not exist, the respective UPS module will  
4 change itself to become a new entrant, and then enter into the arbitration process  
5 for new virtual master.

6 3. The method for controlling parallel operation of UPS modules as  
7 claimed in claim 2, wherein the respective UPS module further possesses the  
8 functional capability of synchronous mode switching, in situations where the  
9 system needs to be switched over all at once at a preset point.

10 4. The method for controlling parallel operation of UPS modules as  
11 claimed in claim 3, wherein the respective UPS module further possesses the  
12 functional capability of an optional wireless control mode, in situation where the  
13 interconnecting communication bus is inoperative the respective UPS module  
14 can decide for itself to switch over to wireless control of parallel operation.

15 5. The method for controlling parallel operation of UPS modules as  
16 claimed in claim 4, wherein the wireless control is implemented using a droop  
17 method, whereby the respective UPS module uses the feedback data from the  
18 output of the UPS module to determine if its output contains more active power  
19 or reactive power, and from which the phase angle and amplitude of the output  
20 voltage signal can be controlled by an appropriate means.

21 6. The method for controlling parallel operation of UPS modules as  
22 claimed in claim 2, wherein the respective UPS module operating in the new  
23 entrant operation mode is able to arbitrate for the virtual master by broadcasting  
24 the manufacturer's ID code onto the communication bus; if the received data is

1 found to contain the same ID code as that previously sent out, the respective UPS  
2 module will configure itself to be the virtual master in the system.

3 7. A modular uninterruptible power supply (UPS) system including one  
4 or more UPS modules connected in parallel, wherein a respective UPS module  
5 comprises:

6 one or more DC inputs and AC input phases;

7 one or more AC output phases;

8 an AC output being connected in parallel to the load;

9 a unit controller with the functional capabilities for self-initiated role  
10 detection, mode switching, and master arbitration through the parallel control  
11 bus; and

12 a parallel control bus for controlling the operation of the local unit and  
13 coordinating the parallel operation.

14 8. The modular UPS system as claimed in claim 7, wherein the system  
15 further includes:

16 a display and communication unit for providing meaningful data to users  
17 with regard to the internal operation and for monitoring software programs;

18 an optional external battery being connected to the DC input for  
19 extending the discharging time;

20 an optional charger for charging all the batteries;

21 an optional output transformer being connected to the output of the UPS  
22 module; and

23 an optional manual bypass switch being installed between the inputs and  
24 outputs of the UPS module.

1           9. The modular UPS system as claimed in claim 7, wherein the AC input  
2 voltage should possess a plurality of phases in one cycle, whereby the UPS  
3 module can be connected by a plurality of wires and switches to adapt to a  
4 multi-phase AC input.

5           10. The modular UPS system as claimed in claim 7, wherein the DC  
6 input comes from batteries, which can be installed in the UPS module, or  
7 externally connected to the UPS module.

8           11. The modular UPS system as claimed in claim 7, wherein the unit  
9 controller of the respective UPS module further comprises a general-use I/O  
10 control circuit, whereby the unit controller is able to control the output power  
11 switch of AC output and the parallel control bus basing on the feedback of  
12 voltage and frequency signals from the DC bus, DC input, AC input and AC  
13 output, and AC input, and output current, and conduction current from the  
14 inverters.

15           12. The modular UPS system as claimed in claim 11, wherein the unit  
16 controller further includes a microprocessor for controlling I/O operations,  
17 output power switch using the feedback voltage and current data from AC output,  
18 and the inter-unit signaling switch.

19           13. The modular UPS system as claimed in claim 11, wherein the unit  
20 controller further includes a photo-coupled bi-directional control bus, a  
21 communication bus and an analog signal synthesis line.

22           14. The modular UPS system as claimed in claim 13, wherein the  
23 photo-coupled bi-directional control bus has one wire used for configuring the  
24 virtual master, and another wire for transmitting sync clocks from the virtual

1 master to synchronize the parallel operation.

2 15. The modular UPS system as claimed in claim 13, wherein the  
3 photo-coupled bi-directional control bus has incorporated impedance matching  
4 on the input and output terminals.

5 16. The modular UPS system as claimed in claim 14, wherein the sync  
6 clocks are directly passed to the input capture of the unit controller for detecting  
7 input and output frequencies.

8 17. The modular UPS system as claimed in claim 15, wherein the sync  
9 clocks are directly passed to the input capture of the unit controller for detecting  
10 input and output frequencies.

11 18. The modular UPS system as claimed in claim 13, wherein the analog  
12 signal synthesis line includes a switch for controlling the synthesis of output  
13 current from UPS modules connected in parallel in accordance with a  
14 predetermined ratio, and the switch is disconnected if found not necessary.

15 19. The modular UPS system as claimed in claim 7, wherein the display  
16 and communication unit is hot swappable, and acts as a source for sync clock  
17 signals received by all parallel UPS modules.

18 20. A UPS module in a modular power supply system has a power unit,  
19 comprising an AC/DC converter, a DC/DC converter, a DC bus and a DC/AC  
20 inverter; and

21 a unit controller built in with the functional capabilities for self-initiated  
22 role detection, master arbitration, and parallel processing, and including an I/O  
23 control circuit and parallel control bus, wherein

24 the I/O control circuits detect the voltage and frequency of AC input,

1 voltage of DC input, and voltage, current and frequency of AC output for  
2 controlling the output power switch of AC output.

3 21. The UPS module as claimed in claim 20, wherein the UPS module  
4 further includes an optional charger and a power supply unit.

5 22. The UPS module as claimed in claim 20, wherein the UPS module  
6 further includes a microprocessor for controlling the inverter operation in either  
7 standalone or parallel connection mode, computing the required duty cycle for  
8 the output power switch, detection of voltage and frequency signals from both  
9 input and output, and inter-unit signaling between UPS modules during parallel  
10 operation.

11 23. The UPS module as claimed in claim 20, wherein the unit controller  
12 has a parallel control bus formed by an analog signal synthesis line, a photo-  
13 coupled bi-directional control bus and a communication bus, whereby the  
14 respective UPS module is able to maintain the parallel connection with other  
15 parallel UPS modules.

16 24. The UPS module as claimed in claim 22, wherein the UPS module  
17 can use the microprocessor and the parallel control bus to elect a virtual master  
18 through an arbitration process to be responsible for synchronizing the output of  
19 all parallel UPS modules.

20 25. The UPS module as claimed in claim 23, wherein the photo-coupled  
21 bi-directional control bus is used for receiving signals from other parallel UPS  
22 modules or transmitting signals to other UPS modules.

23 26. The UPS module as claimed in claim 25, wherein the photo-coupled  
24 bi-directional control bus has a wire used for transmission of sync clocks to the

- 1 input capture of the microprocessor in the unit controller..